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# Sketching the Future: Assessing User Needs for Domestic Robots

JaYoung Sung, Henrik I. Christensen, and Rebecca E. Grinter

***Abstract*—In this paper, we discuss a user-centered vision of future domestic robots based on 48 householders' depiction of their ideal home robots. Through users' creative responses, we aim to identify domestic tasks desired for robotic assistance, and hence guide the design effort to better reflect user needs. Our study results show that householders want domestic robots for tasks including Time-consuming Drudgeries, House-sitting, and Personal Attendance. Further, we present three design lessons we learned to increase householders' acceptance of these robots. The design of domestic robots needs to provide a certain amount of human control, be compatible with the user's domestic environment, and take gender into consideration.**

## I. Introduction

SCIENCE fiction movies, cartoons and novels have long depicted our future with domestic robots. Popular examples include Rosie from the Jetsons and C3P0 from Star Wars that assist, replace and extend human capabilities in the home. But today, these visions of robots do not seem so far from reality. The number of domestic robots being adopted is growing exponentially each year and the range of household tasks they can perform continues to expand into new domains such as nursing, entertaining and cleaning [1]. Despite this transformation from fiction to fact, a gap exists. To date there is a surprising lack of scientific understanding about what users need and desire for robotic assistance at home.

To address this gap, we turned to users and learned what they want in their ideal domestic robot. Specifically, we undertook a generative design study ([2,3]) with 30 households (48 participants) in Atlanta, U.S. Using well known design elicitation techniques, our approach consisted of asking individuals to visually create their ideal home robot using a variety of materials (Fig 1).

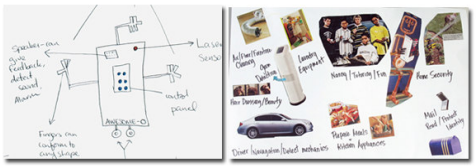

Fig 1. Generative design activities on ideal home robots

Through users' responses, we aimed to 1) identify commonly desired tasks that robots could assist with, and 2) derive design guidelines that promote acceptance of these robots. Our paper begins by reviewing the related work. Then, we present three categories of tasks that people wanted domestic robots to perform: *Time-consuming Drudgeries*, *House-sitting*, and *Personal Attendance*. Finally, we conclude with a discussion of what designers should consider in order to make domestic robots more inviting to domestic spaces.



JaYoung Sung is with Georgia Institute of Technology, Atlanta, GA 30308 USA (corresponding author, phone: 404-429-1354; e-mail: jsung@gatech.edu).

Henrik I. Christensen is with Georgia Institute of Technology, Atlanta, GA 30308 USA (e-mail: hic@cc.gatech.edu).

Rebecca E. Grinter is with Georgia Institute of Technology, Atlanta, GA 30308 USA (e-mail: beki@cc.gatech.edu).

## II. Related Work

In this section, we situate our project with respect to related work that has contributed design directions for future robots. We present this in three groups of: 1) the studies that surveyed robots in the market, 2) the studies that empirically explored robot usage in real world, and finally 3) studies that conducted technical experiments.

Market reviews of current domestic robots have been used to identify technical limitations and affordances, and offer suggestion for improvements [4-6]. Prassler et al. reviewed 30 different cleaning robots including commercial and research types, extracting technical requirements [6]. Subsequently, they expanded this work to include lawn mowing, ironing, digital wardrobe, and smart home applications [5]. Christensen reviewed domestic robots and categorized them by their task domains, such as entertainment, everyday tasks, assistance [4]. Then, he discussed key design issues, such as localization and mapping, and user interface.

The second group focuses on empirical investigation of usage patterns of existing robots [7-11]. Collectively, this research has provided rich and contextual accounts of robots' impacts on households and has identified implications for future development. For example researchers studying vacuuming robots found that it increased both opportunistic and planned cleaning [8]. Also, they found that the robot impacted the social dynamics of the house by making the cleaning activity a concern for all householders as opposed to a single person [7]. Further, researchers report cognitive and emotional responses among householders triggered by the symbolic value of the robot as a pet or being perceived to be a part of the household [8,10,12], which in turn lead to better caretaking and the likelihood of long-term adoption [10]. Thus, empirical findings have led to design implications that a robot's ability to navigate to a specific spot in addition to the entire house is important [9], and that its form factor should be configurable to elicit human engagement with a robot [13].

The third group of work focuses on generating guidelines for domestic robots based on technical experiments intended to elicit design criteria [14-16]. Guidelines include, but are not limited to, path planning and execution [16], and energy

optimization [15]. Also, they have identified non-technical guidelines, such as safety (e.g., interaction with children) [15,17], and forms [14,15] (e.g., low profile with round edge).

Thus, scholars have provided design insights for future domestic robots by surveying existing robots, observing actual usage, and experimenting with technical possibilities. Yet, far less research has addressed design opportunities for future robots through asking users directly about their needs. Some have started this dialogue. Scopellini et al. [18] conducted a survey with 120 people to identify attitudes and perceptions about future domestic robots (e.g., asking how people would feel if they had a robot cooking for them). However, their study focused on perceptions and did not seek a full list to tasks people wanted future robots to perform. Dautenhahn et al. [19] took an initial step to identify tasks by conducting a psychological experiment with 28 adults. Their study revealed that people want to view their home robots as machines, assistants and servants, performing vacuuming, security, entertainment, gardening, and child-care tasks. In our paper, we build upon this work by offering a larger and detailed number of task domains, and design recommendations for the identified tasks. In the next section we describe our approach and participants.

### A. *Study Methods*

We chose a generative design approach to collect data because it supports gathering user's insights by making them do as opposed to talk and being observed [3]. Its descriptive and unstructured nature helps amplify the thinking process and reveal human needs that are often difficult to express in words [2,3]. Considering the unusual nature of the study topic (future domestic robots), and some participants' technical naivety, we felt this method would help surface participant's insights, needs and desires.

During the study, each participant was given a large sheet of blank paper (24 inches by 18 inches) and asked to create visual description of their ideal domestic robot without considering any technological constraints. To help them, we provided a range of generative tools such as magazines, colored paper, pens, and so forth. We did not encourage writing unless they did it for labeling their creations. People expressed their visions of future robots in various ways. Some drew a robot with detailed functionality, such as an LED panel for human-robot interaction (Fig 2 left). Others created a collage of desired functions such as using a smart phone image to explain that the robot organizes their schedule (Fig 2 right). The goal was to use this visual approach as props to support in the ideation process of creating a future domestic robot.


Fig 2. Generative Design Style: a Hand-drawn Robot (left), and a collage of images that contains desired functions (right)

When participants had finished, we asked them to explain their robots. This included asking them about the overall concept and motivation for the robot, and then turning to detailed descriptions of function, forms, interactions, and anything else the visual diagram suggested to us to ask. We audio-taped and video-recorded participants' narratives, which we subsequently transcribed and analyzed.

### B. *Study Analysis*

We used qualitative analysis methods because our data contained unstructured and narrative information. We first extracted 99 discrete tasks that people want a robot to perform from the transcripts. Then, we began grouping them using an affinity diagram technique, an inductive analysis that categorizes similar key points to identify overarching issues in a given context [21]. During this process, we used the domestic tasks defined in the "Dictionary of Occupational Titles" (a U.S. Labor Department standard for categorizing domestic services) [20] as an index for categorization. We did this to increase validity in the analysis process by keeping the inductive grouping closer to the existing taxonomy of domestic services. Also, it allowed us to identify what types of labor people would feel comfortable to have a robot replace. However, we did not limit our data to the existing list of domestic tasks described in the dictionary. People also created new tasks that relied on their robots' computational capabilities, such as germ detection and protection from identity theft. Our analysis continued until we had grouped the identified tasks into three broad categories: Time-consuming Drudgeries, House-sitting, and Personal Attendance.

Once we established these three categories, we analyzed the transcripts again to identify design implications. We first established an analytical framework based on existing guidelines for a cleaning robot [15] and a social robot [22], and used that as a guide to identify design guidelines in our transcripts. The framework we derived included six categories of design considerations: form factor, interactivity, intelligence, operation, sociability, and environment. Then, we used this initial division to compare differences in design requirements for each task domain as well as common considerations across all of them.

### C. *Participants*

We had 48 participants (22 men and 26 women, mean age=42) across the 30 households. More specifically, we had 12 single-headed households and 18 double-headed households. We would describe 19 of our participants as technical, meaning they had received professional or academic training in engineering-related fields, or reported having technologically-oriented hobbies such as hacking. No participants owned any domestic robotic appliances. Finally, given our focus on cleaning, we also recruited families with pets (n=16), and families with cleaning services (n=7). Among the seven who hired cleaning services, six received the service every other week and one did it once a month.

## III. FINDINGS

In our study, participants reported 99 distinct tasks that they wanted domestic robots to perform. Some of participants imagined automating manual labor including, loading dishes into dishwasher and sorting laundry. Others wanted help with expert knowledge, such as how to maintain their vehicle. Fig 3 provides a list of individual tasks our participants preferred.

However, all of our participants wanted a robot that performed multiple tasks, described as a "*Swiss army type*" by P2. They noted multiple functionalities increased motivation for adoption as it justified the potential cost. Therefore, we discuss robot tasks in larger groups of similar tasks, such as *Time-consuming Drudgeries, House-sitting and Personal Attendanc*e to inform the design of multi-functional robots.

### A. *Time-consuming Drudgeries*

Time-consuming drudgeries include tasks related to cleaning, yard work, and cooking (refer to Table 1 for some but not all examples of tasks under this domain). Our data suggests that this task domain was the most desired one. The number of tasks under this domain appeared 103 times during the interviews, outnumbering the other two categories almost twice as much (House-sit appeared 50 times and Personal Attendance appeared 62 times). All but three participants (n=45) mentioned at least one type of time-consuming drudgery as a desired robot task.

TABLE 1
EXAMPLES OF TASKS UNDER TIME-CONSUMING DRUDGERIES

| | |
|---|---|
| Cleaning | Vacuum (n=6), wash dishes (n=9), laundry (n=7), clean tub (n=4) |
| Yard Work | gardening (n=7), watering plant (n=3) |
| Cooking | cook (n=12), food preparation (n=5) |

Participants desired robotic assistance in the seemingly "*endless*" drudgeries to regain time for activities they enjoyed such as playing with children and pets, and self-development through study and work. Even those who hired cleaning services saw the advantage of having a robot because they would not feel guilty for making people do the work they found "*unpleasant*" and "*boring*".

For participants, multi-functionality seemed a key factor for adopting robots that performed time-consuming drudgeries. Our participants who had professional cleaning services expressed interest in replacing the human service with a robot one only if it provided equal or greater number of tasks. In addition to performing multiple functions, users also wanted it to do things that are difficult such as cleaning air ducts, under furniture, and ceilings. They noted that it would save both time and money by reducing either the amount of time to find the right tool or the cost of hiring people to do it.

Of course, our participants understood that more functionality would mean higher costs and potentially lead to a larger sized robot. To resolve this, some suggested making robots compatible with existing tools at home. For instance, P2 and P7 designed robots that had connectors to attach to the vacuuming hose for cleaning and water pipe for watering plants (red circle in Fig 4). By working with existing tools, it may reduce unnecessary parts, and retain desirable forms.

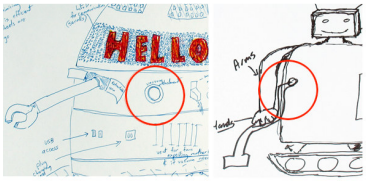


Fig 4. Depiction of robot's connector to existing tools

Another key factor was to minimize mechanical and operational noise from the robot. People did not want their robot to interfere with their other activities such as watching TV, playing with children and sleeping. Also, they told us that noise would cause problems in presence of children and pets. Two participants specifically chose wheels over legs because they thought it would create less noise by increasing smoothness in movements.

As much as people spoke of automation of time-consuming tasks, they did not want too much robotic intelligence (also referred to as decision-making power). This was especially true for the tasks that required expert knowledge or involved safety risks. For these tasks, people stressed wanting to work with the robot as opposed to having the robot conduct the entire task. For example, householders wanted to create their own recipes, but have the robot perform tasks like grilling and boiling. Men appeared to be more sensitive about this issue. For example, the husband in P27 stressed that it would only assist in simple food preparation while his wife spoke about how a robot could help with "*light cooking*":

*"I intentionally said easy food things. I don't know if I would trust a robot with a knife and chop things but very simple preparation... don't want to risk if something goes wrong."*

Participants also wanted time efficiency in the mode of interaction for these robots. They strongly preferred speech (*i.e.*, voice commands) and auditory feedback as the main means of interaction. One participant (P12) drew ears on a robot to represent the importance of this modality. Another reason to prefer audio interaction was that people foresaw their robots being in places (like the ceiling and gutter) where they could not press buttons.

Unlike operation or intelligence, participants did not express as much interest in aesthetics. Instead, they focused on the function more than form. For example, P25 stressed how functionality came before form factor while describing a robot that supported manual tasks, such as laundry and doing the

dishes. In his words:

*"I don't need it to have human appearance, or to be a guy or a girl or an animal. The factory robot looking is fine with me. I don't also need companionship or social relationship with the robot. It just needs to do the work to make my life easier."*

### B. House-sitting

Participants relied on robot's sensing capability and computational superiority to support house-sitting. According to [20], a house sitter as someone who oversees a home to maintain order and security. Within this category, people wanted a robot to perform hygiene and health inspection, resource management, and security control as in Table 2.

TABLE 2
EXAMPLES OF TASKS UNDER HOUSE-SITTING

| | |
|---|---|
| Hygiene & Health Inspection | health diagnosis (n=3), germ control (n=3) |
| Resource Management | inventory cataloguing (n=6), temperature & light control (n=3) |
| Security Control | property security (n=7), answer door (n=3), bodyguard (n=2) |

First, people desired a house-sitting robot to maintain a healthy and hygienic home through monitoring what can not be seen by the human eye: germs and allergens. Also, our participants wanted robots for detecting health concerns such as high cholesterol levels and communicating that to doctors to get further instructions. Here, we encountered a tension between not wanting to give the robot too much decision-making power and still wanting to make it intelligent to do the task. That is, people wanted the robot to be able to perform health checks by collaborating with some medical establishments to reduce unnecessary doctor visits, but always in consolation rather than autonomously. One elderly participant (P18) spoke about a robot that could detect an emergency situation and make the necessary call. However, she did not want her robot to administer a medical treatment.

Second, participants wanted a house-sitting robot to manage resource consumption including light, temperature and water usage, particularly during their temporary absence. In addition, six people wanted robots to help manage information compiling process, such as cataloging household inventories. Participants desired a robot to prompt them when things expired or needed restocking, but stressed that it should not make decision-involving actions such as shopping based on the inventory information.

Finally, participants imagined a robot that could monitor their physical property. In most cases, participants wanted a robot patrolling the house (both inside and outside). Like the health monitoring robots, people spoke of a systematic collaboration between mobile robots and surveillance systems in the house as a preferred mode of operation. P4 described a robot that roamed around the house to clean in normal mode but would pull out a weapon when the security sensor in the house detected abnormal vibration or sound (Fig 5). P4 was unusual; the other six households who described a security robot did not want the risk of having an armed robot. Instead, they spoke about their robot as having a loud alarm or being able to contact security agents.

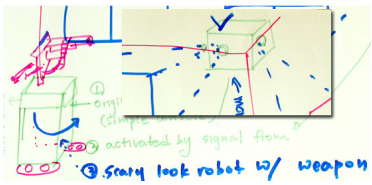


Fig 5. P4's security robot that works with a camera. The wheel and gun disappears when inactive, making it look like a fixture.

Overall, the key design factor for a house-sitting robot appears to be the robot's capability to collaborate with other units in a systematic manner. For instance, a house-sitting robot needs to collaborate with a cleaning robot to disinfect the germ detected area, or arrange communications with health establishments and security agents for necessary aids. Further, participants spoke of a way to interact and communicate with the robot such as remotely viewing the activity log as it would run frequently during their absence. Thus, householders certainly wanted a house-sitting robot more intelligence than one that performs a repetitive manual task, and foresaw collaboration with an existing system or a robot as a way to maximize its utility.

Participants did not pay much attention to the aesthetic quality of this house-sitting robot. However, they desired flexible form factors to serve both indoor and outdoor security assistance. For example, people wanted to take the robot outside as a bodyguard, describing its form as strong and tough, such as that of "Darth Vader" from Star Wars. However, they insisted it should transfer into an eye-pleasing form when inside the home such as "Nicole Kidman" (Fig 6).

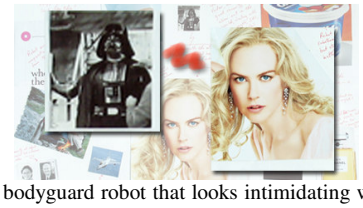

Fig 6. P9's bodyguard robot that looks intimidating when outside but changes to an eye-pleasing form when at home.

### C. Personal Attendance

According to [20], a personal attendant serves a need such as managing wardrobes, serving refreshments, applying cosmetics and more. Our participants wanted personal robotic assistances in intellectual and emotional support (Table 3).

TABLE 3
EXAMPLES OF TASKS UNDER PERSONAL ATTENDANCE

| | |
|---|---|
| INTELLECTUAL SUPPORT | |
| Organizer | report news (n=7), scheduling (n=3) |
| Instructor | financial help (n=2), fitness trainer (n=3) |
| EMOTIONAL SUPPORT | |
| Beauty Support | hair & make-up (n=6) |
| Mind Relaxation | massage (n=6), refreshments (n=5) |
| Entertainment | play movie & music (n=3) |

Participants desired robotic assistance with intellectual support such as efficiently managing and organizing information. They wanted a robot to filter out interesting news,

and search and compile information on demand, such as product user reviews. P20 highlights this robot as:

*if we are looking a new product, (it would) go and get all the review…that sort of tedious and time consuming information compilation tasks. Again, it's not about decision making but automating some of the time consuming tasks"*

Also, people sought robotic support in more complicated tasks than information parsing. Ten participants depicted a robot that could instruct with specialized knowledge, such as child education, financial investment, and fitness maintenance.

Further, participants illustrated a robot that supported them emotionally. In particular, women who lived alone described a robot's assistance in improving their mood through serving cocktails and sweets, and assisting with beauty care including, pedicure, hair-care, and makeup. In addition to these services, people wanted a robot companion who could tell jokes and share conversation in deeply personal matters.

For these robots performing as personal attendants, our participants seemed open toward having a smart robot, even to the level close to human intelligence. Two participants expressed that this type of a robot should reinforce their intelligence by offering information beyond their expertise, such as teaching how to invest money and tutoring math to her 6-year-old granddaughter. However, even in these more intelligent and autonomous robots, householders did not want the robot to have the power of decision-making, such as being able to buy and sell assets. Personal Attendance appeared as a domain that participants spoke strongly of robot's sociability. People wanted to live with a friendly robot that they would want to keep around for a long time. However, householders clearly stated that they did not want a robot that acted as a friend but as a professional butler (as also reported in [19]). They associated friend-like actions as potentials for not acting politely and being less dedicated to the task. Also, participants envisioned that the personal attendant robot should have social skills as they wanted it to help with hosting guests by engaging in conversation and telling jokes. But they rejected the idea of more intrusive means of entertaining, such as singing and dancing. In a word, people valued a robot's capability to act socially with subtly.

In addition to sociability, our participants actively discussed about form factors. They expressed specific preference including gender, size, and aesthetic qualities for personal attendant robots (Fig 7).

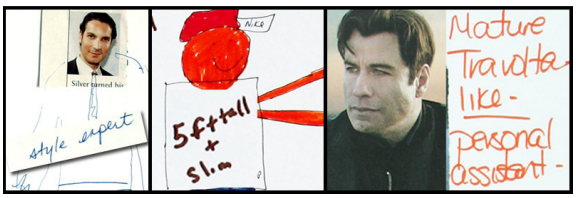


Fig 7. P1's professional looking butler robot (left), P11's do-it-all robot that dresses nicely and has a slim figure (middle), and P10's personal robot that has the mature John Travolta look (right).

Whether the robot took an anthropomorphic form or not, people agreed that a robot could provide a comfortable and eye-pleasing form beyond "*older notion of servant or housekeeper (P23)*", such as a humanoid robot wearing a maid uniform. The wife from P25 discussed how the aesthetic quality was important to get engaged with the robot,

*"I want it to look like a pet but modern and fit into the home. When I say I want it to be like a pet, I would like to be able to say, 'I would like to have you around'. I don't want it to look like a dog (but) something really adorable and cute."*

Householders spoke of emotional comfort and pleasure not only in the form factors, but also in the mode of interactions. P25 stressed the importance of having haptic interaction modes as people touch and pat to show affection. Also, P8 reported that a robot's ability to speak in natural human tone was critical particularly when educating children so that they would not only feel comfortable with robot's presence but also have respect for it as they would do with a human adult.

Finally, this domain exhibited an interesting gender disparity. Out of 15 participants who mentioned at least one task belonging to Personal Attendance, 11 of them were women. More specifically, any tasks that reinforced emotional support, such as giving massage and assisting with beauty care all came from our female participants.

## IV. DISCUSSIONS AND CONCLUSION

Thus far we have reviewed design opportunities for future home robots in three domains of: Time-consuming Drudgeries, House-sitting, and Personal Attendance. In this section, we discuss three important lessons we learned during this process with regards to how we should design to increase householders' acceptance of these robots.

First, our findings suggest that the design of domestic robots needs to provide a certain amount of human control over a robot's intelligence. As much as people wanted the robot to perform tasks with quality without supervision (i.e., working autonomously), they desired to assure its compliance by restraining the decision-making power. The desire for human control appeared stronger if a robot's performance could risk human safety, such as using knives and drills. As a result, people chose to work with robots rather than having it conduct the entire task, such as sensing and alerting abnormal conditions of the home but not taking any direct actions against it. Even for a robot that had a high level of intellectual and emotional capabilities, participants desired a way to control, such as being able to turn it on and off. Participants sought compliance not only in robot intelligence but also in its form factors. All of our participants drew robots equal or smaller on size to themselves, associating it with obedience and compliance (also supported by [23]). P12 explains this as:

*"He (referring to the robot) must be shorter than I am. It's just like with animals. Animals tend to get more aggressive if you get down to their level. But they are more listening to you because you are above them. I would have to say the same thing with the robot."*

Second, our findings suggest that the robot should work compatibly with a domestic environment with regards to its technical operation and visual appearance. Participants foresaw robots' technical compatibility with existing tools, embedded sensors and communication devices as a means to

make it perform multiple tasks at reduced cost, and hence increase its market value to consumers. Furthermore, householders emphasized that the visual appearance of robots should match the interior of the house in order to feel more comfortable to adopt it. The robot form such as shape, color and size is known to play a key role in increasing the acceptability among the householders [17]. To increase a robots' visual compatibility, our participants suggested a flexible form that resembled a fixture when inactive, but metamorphose to serve its practical purpose when in operation. People further discussed this flexible form in foldable and modular units as a way to easily store and carry it on a trip.

Third and finally, we saw contrasting needs between genders in desired robotic tasks and the design specifications that follow (Fig 8). In general, women sought a robot that could promote the quality of their lives. For instance, they wanted a robot to complement their physical and intellectual capability, such as reaching higher places, and advising


Fig 8. Gender implications: P12 (man)'s robot for tool storage and delivery vs. P9 (woman)'s cute looking robot for beauty assistance

financial investment. In contrast, men wanted a robot to execute and serve their orders like an apprentice or a servant. The desired tasks included tool delivery and food preparation according to the recipe instructed.

Overall, this strong gender influence indicates the importance of understanding the needs of a target group and design to meet their specific desire. Similarly, Bill Buxton argues that the design of a technology with multiple functionalities should aim for *Strong Specific* (a small number of well-designed functions) as opposed to *Weak General* (several functions with little relation to user needs) [24]. Although our study revealed strong gender differences, we contend that more attributes such as age, ethnicity and technical background could drive the variance in user needs of future robots. Therefore, we call for attention to cultural and demographic impact on vision and expectation toward domestic robots.

We conclude this paper by outlining our two main contributions. First, we have identified three task domains that householders desire for robotic assistance including, Time-consuming Drudgeries, House-sitting, and Personal Attendance. For each domain, we have provided a list of specific tasks and design requirements that need be considered, such as intelligence, interactivity, and aesthetics. Second, we have discussed that the acceptance of these robots would increase if the design ensures a space for human control, enhances compatibility with domestic space, and understands gender specificity. Domestic robots grow in adoption each year, and hence we contend that now is the right time to uncover user needs and desire for future robots. Here, we took an initial step towards creating a dialogue in the Ro-Man community about what direction we, as designers, should take to make these robots more accepting to our domestic spaces.

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